Pump Drainage in the Southeast

by

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It is a great pleasure for me to appear on your program today. Before we consider the details of the subject I would like to point out that drainage pumping is of great importance to the future development of the Southeast. Drainage pumping plants are used in situations where it is not possible or not economical to obtain an outlet through gravity drainage ditches. In the Southeast there are considerable areas, especially along the coasts, and some rivers which are flat and relatively low in elevation. Drainage pumping may enable the future reclamation for agricultural uses of many of these marshes and tidelands. It is possible that large areas of tidelands can be reclaimed by using the techniques now known. Some attempts have been made in the United States to reclaim lands lying near sea level but these works have generally been favorably located away from the direct wave action of the sea. The reclamation of tidelands would be expensive because dikes must be large to hold out the storm tides and the revetment and protection would be costly. Under prevailing conditions of crop surpluses and for some years to come there is not likely to be too much demand for additional land reclamation of this type. Where low lands are located away from the ocean tides their reclamation is much less costly.

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Pump drainage in this paper is confined to discussion of drainage by pumping primarily for drainage of agricultural land. However, many pumping plants installed for pumping runoff from urban areas or sewage are similar in design to pumping plants for agricultural lands.

The largest and most significant current development of drainage pumps in the Southeast are those installed by the Corps of Engineers in the Florida Everglades. These are among the largest pumps in the world. Some of the principal features of this pumping development will be described in this paper. In addition to these large pumps in the Everglades areas, there were 99 drainage enterprises using pumps in Florida reported in the 1950 census. These enterprises operated 354 pumping units and served 293,124 acres. Louisiana, which usually is not classified among the southeasten states, is the only other southern state with a large number of drainage pumps. The 1950 census reported 102 pumping units operating in 30 enterprises. The area served by pumps was 179,266 acres. Large drainage pumping plants drain the New Orleans metropolitan area.

There are also a considerable number of small farm drainage pumping plants in the Southeast. No estimate is available as to the number and total acreage drained but technicians in the Soil Conservation Service have examined and provided technical assistance on many farms having such pumping units. These pumps drain from less than 100 up to several hundred acres. Many of these are

light propeller-type pumps manufactured by local machine shops. Others are substantially constructed pumps made by leading manufacturers. Most of these farm pumping plants are located near the coast from North Carolina southward. The typical pumping installation in the Southeast includes a dike surrounding the area to be pumped, an open ditch system to drain the water from the fields to the pumping plant, and a pumping plant to lift the water from the drainage ditch into the outlet.

Design of pumping plants.

The general quality and type of a pumping installation will depend upon the size and importance of the installation. Where a pumping plant drains a considerable number of farms and the farmers are entirely dependent upon the regular operation of the pumping plant it is, of course, desirable to utilize the best and most dependable plant and equipment available. More than one pumping unit should be used in such installation so that the land will have some drainage when one unit is being repaired.

Farm installations have been characterized by efforts to save on initial costs of the plant and building. Economy on first cost of many of these plants has been by use of pumps manufactured by local machine shops. Frequently, farm tractors or old automobile engines have been used to drive such pumps. Most of farm installations have submerged pumps and an open discharge pipe which eliminates need for vacumn pumps which would be required if it were necessary to prime the pumps.

Inexpensive structures have been used to house many farm pumps. Such installations are subject to fire hazards. Many farmers are not entirely dependent upon the pumping plants for their livelihood and can well afford to take the chances on breakdown and interruption of services incident to using a low-cost pumping plant.

The following comments on design are more particularly applicable to small farm-size pumping plants. The design and operation of drainage pumping plants is discussed in Technical Bulletin No. 1008, prepared by the writer and published by the U. S. Department of Agriculture, May 1950. This bulletin covers in detail the considerations recommended for design of large and medium-size drainage pumping plants.

Determination of runoff to be pumped.

The runoff to be pumped often includes, in addition to the normal flow from drains, a large amount of seepage from nearby hill lands and from bordering rivers or creeks.

The rate of surface runoff depends on the amount, intensity, and distribution of rainfall and other precipitation, storage, the size and shape of watershed, the ground slopes, the vegetal cover, and the character of soil. The rate of seepage from hill lands is often an important factor in pumping requirements and its amount depends upon the local conditions. The rate of seepage from adjacent bodies of water depends especially upon the difference in elevation of the water inside and outside the drainage district,

the extent of water-bearing gravel and sand under the district, and the length and location of drains touching the water-bearing strata. Because of the large number of influencing factors, the amounts and rates of runoff to be pumped can best be estimated from comparisons with similar areas from which the drainage runoff pumped has been measured.

For the design of a drainage pumping plant careful estimates should be made of (1) the average yearly runoff, (2) the seasonal distribution of that runoff, and (3) the maximum daily runoff.

The yearly runoff must be known in order to estimate the annual cost of pumping and determine the feasibility of the project. The seasonal distribution of the runoff as well as the lifts must be known in order to design an efficient pumping plant. The maximum daily runoff determines the total capacity of the plant and is considered one of the most important determinations to be made in designing any pumping plant. This determination should be made locally based on conditions encountered.

<u>Maximum plant capacity</u>.

When the runoff from rainfall exceeds the capacity of the pumping plant, the excess runoff goes into storage. This storage includes, (1) ground storage resulting from a rise in the groundwater table, (2) ditch storage, and (3) surface storage in sloughs and low areas. Storage may occur at locations away from the pumping plant and not be reflected in a large or rapid rise of the suction bay. Evaporation and transpiration losses of water help

to dry up a drainage district, especially during the growing season.

Crop losses result when the pumping plant capacity is inadequate because of flooding of low areas or of a high ground-water table. It is economical to provide a large pumping capacity to protect land or crops of high value.

The pumping capacity includes runoff from gravity plus seepage which occurs in pumping districts minus storage.

These relationships may be expressed as follows:

$$\text{Maximum plant capacity} = \begin{matrix}\text{gravity}\\ \text{drainage}\\ \text{runoff}\end{matrix} + \begin{matrix}\text{seepage}\\ \text{runoff}\end{matrix} - \text{storage}$$

The required plant capacities in Florida were studied by B. S. Clayton, Drainage Engineer, Soil Conservation Service, who conducted long-time investigations in the Florida Everglades. He found that many of the northern Everglades pumping districts serve from 5 to 13 sections of land. Most of these pumping plants were designed to remove 1-inch runoff per 24 hours. Much of this land is used to grow sugar cane. Experience over a 20-year period indicates that the 1-inch rate is generally ample for growing sugar cane on the organic soil of the area.

It was found, however, that truck crops suffered losses where the capacity was only 1-inch per 24 hours. As a result of Clayton's investigations the following rates are recommended for land used for growing truck crops in organic soils; 3.0 inches for 1 section of land or less, 2.0 inches for 2 to 3 sections of land, 1.4 inches for 4 to 9 sections of land, and 1.0 inch for 10 to 16 sections of land.

In recent years a considerable number of pumping plants have been installed to serve land used for growing pasture grass for cattle. These pumping plants usually drain from 2 to 4 sections of land. A runoff of from 1 to 2 inches was commonly provided for these grazing areas and appeared to be adequate.

For mineral soils in the Southeast, E. A. Schlaudt of SCS, Spartanburg, recommends for areas less than 1 square mile;

2 inches per 24 hours from watershed for improved pasture
3 inches per 24 hours for general crops
4 inches per 24 hours for truck crops

These coefficients should be increased for high value truck, fruit, and other crops.

In northern states the required capacities are much less. For general crops a coefficient of 1 to $1\frac{1}{2}$ inches per 24 hours is usually used in Ohio and Illinois for farm-size plants.

Kinds of pumps

The axial-flow or propeller pump is the most efficient type for the low lifts less than 10 feet usually found in the Southeast. This pump has several blades shaped like a ship propeller and is sometimes called a "screw" pump. Some pumps of this type are constructed so that the water may be reversed in direction and the pump used for both drainage and irrigation. It is important that some provision be made for reversal of flow to obtain water control, especially for organic soils.

Some low-cost propeller-type pumps have been manufactured by local machine shops, using a propeller similar to a boat propeller

inside a welded steel pipe used for a casing. The design and efficiency of the so-called "homemade" pump varies greatly. Many of these pumps have been installed for drainage of fields less than 200 acres. The principal advantage of this kind of installation is the low initial cost. A pump to drain the average-size farm can be obtained for several hundred dollars. Such a pump can be operated by a tractor, an engine, or an electric motor.

The buildings and foundation are usually simple and inexpensive since large volumes of water at high velocities are not handled. Small farm-size pumping plants are no more difficult to operate than farm equipment. The annual cost of such pumping, including interest and depreciation is usually less than $5.00 per acre per year. Such installations are subject to failure from different causes; for example, blocks of wood may puncture light casing or the poorly constructed foundation may fail. However, we need to recognize that the low cost of such units justifies considerable risk on the part of the farmer. In many instances he could not purchase a well-designed pumping unit.

The mixed-flow pump combines the centrifugal and propeller principles and is often recommended for operation at heads around 15 feet.

The centrifugal pump itself is not common in the Southeast. It is best adapted to lifts above 15 feet. Such high lifts are unusual in the Southeast.

Most of the farm pumping plants have submerged propellers. The chief advantage of this type of installation is that no priming equipment is necessary. This is an important factor in small plants. It decreases the initial cost and makes for ease of operation. A submerged pump, however, is difficult to clean. Usually, it is desirable to provide hoisting equipment to lift the pump above water to clean trash from the impeller. Well-designed and ample screens are desirable to prevent trash from getting into the pump.

Speed adjustment.

Speed adjustment of drainage pumps is particularly desirable for the plants which handle a lot of water during a year. Pumps are basically designed to operate against a certain lift at design speed. They need to be slowed down to obtain maximum efficiency at lower lifts. Speed adjustment is ordinarily easy to obtain in gasoline engines and in diesel engines. Where electric motors are used it is more difficult to adjust the speeds. This can be accomplished by changing the size of pulleys for belt-connected units. Some of the large pumps have two synchronous motors set on the same shaft which operate at different speeds.

Number of pumps.

In large drainage plants two or more pumps are desirable to provide protection in case of breakdown of one unit. Experience in such plants indicate that needed flexibility is obtained by having 3 units of the same size or having 2 units, one with twice the capacity of the other.

Size of pump.

For preliminary computation the size of pump is usually computed on the basis that the water will discharge at the rate of 7 to 9 feet per second through the pump. This velocity is computed at the pump discharge. The required discharge is based on the total watershed area and the selected runoff coefficient expressed in depth per 24 hours. A convenient unit to use in making this computation is the ratio that 1-inch runoff per 24 hours is equal to 18.857 gallons per minute per acre or 26.889 cubic feet per second per square mile.

Static lift and total head.

In planning pumping plants and in estimating costs, it is important to make engineering surveys for estimating the maximum, minimum, and average static lifts. The pump manufacturer will need these data in order to supply efficient equipment. The static lifts will control the selection of the type of pump.

The range in lifts is required in determining the size of the motor or engine. The maximum horsepower required to drive a pump varies according to the pumping lift. For the centrifugal pump, the horsepower is generally at a peak at a low lift and falls off at higher lifts. On the other hand, for a propeller pump, the brake horsepower required increases as the lift increases.

Characteristic curves are the usual means of showing pump performance. Such curves generally show (1) discharge expressed in gallons per minute (g.p.m.) plotted against total head (feet);

(2) brake horsepower (b.hp.) plotted against discharge, and (3) pump efficiency (percent) plotted against discharge. The three curves need to be shown for each speed if the pump operates at more than one speed.

Usually, drainage pumps may be furnished with the maximum efficiency something over 80 percent. A well-designed pump should have an efficiency above 70 percent over a wide range of operating lifts. Important pump installations are usually supplied by a manufacturer based on specifications prepared by the purchaser. The purchaser specifies the requirements at maximum and other operating lifts. Generally, the manufacturer supplies a set of characteristic curves to the purchaser. Most manufacturers base such curves on factory tests of the pump furnished or on the tests of a geometrically similar pump.

Pump efficiency.

Pump efficiency is computed by the following formula:

$$e = \frac{\text{g.p.m.} \times H_t}{\text{b.hp.} \times 3960 \times e_t}$$

where

e = pump efficiency
g.p.m. = gallons per minute
H_t = total head on pump (feet)
b.hp. = brake horsepower (output of motor or engine)
e_t = transmission efficiency of belt or gear connecting engine or motor and pump. (ratio, i.e. 97 percent = 0.97)

For units where the pump is directly connected to motor or engine e_t is 100 percent, and b.hp. is equal to the horsepower input into pump shaft. For belt-connected units e_t ranges from 95 to 98 percent since only a small loss of power results.

Discharge and suction pipes.

Discharge pipes should go over the levee near the high water level in most drainage pumping installations. If the pump is not submerged the end of the discharge pipe should be below the low-water stage of the discharge bay so that the pump may be primed easily. This arrangement of the discharge pipe permits a siphon action in the discharge pipe which reduces the total head on the pump and the power used for pumping. Where the discharge pipe is submerged, an automatic flap gate should be installed on the end of the pipe to prevent backflow through the pump when it stops.

An alternate arrangement is for the discharge pipe to discharge above high water in the discharge bay. This arrangement, although less efficient, is ordinarily used in small plants in combination with a submerged pump. This eliminates the backflow through the pump and is the safest and most practical arrangement for automatic operation.

The friction losses in the suction and discharge pipes may be reduced by designing the pipes to expand from the connections at the pump. This is of more importance in the large plants. A rounded entrance for the suction pipe is recommended. The expansion of the suction pipe permits the suction bay to be pumped low without the pump losing its prime.

Location of pumping plant.

The location of the pumping plant is determined largely by the topography of the area and the location of the outlet stream or body of water in which the pump is to discharge. Some areas may have alternate locations and selection may be based on the advantages with respect to foundation conditions, construction of drainage ditches, proximity of roads, living quarters, and power lines for electric plants.

Foundation conditions should be determined by means of soil borings. The site should have stable foundation material. A good foundation is a safety factor during flood conditions. Some pumping plants have been destroyed by levee breaks at the pumping plants due to quicksand or other unstable material at or near the plants.

Buildings and suction bay.

The buildings used to house drainage pumping units vary greatly, depending upon the type of installation, size, type of power, soils and foundation conditions, and desires of the owners. Many drainage districts have attractive masonry and steel fireproof buildings resting on piling. In contrast, some pumping units are set on skids on the ditch bank with little or no housing. Because of the volume of water passing through at high velocity, a substantial foundation and well-designed suction bay are mandatory to prevent undermining of large drainage pumping plants.

As the size of the plant decreases there is a greater choice permissible in type of construction and foundation since erosive forces are less. A small substantial fire-resistant building is a good investment even for farm pumping plants. Electrical and accessory equipment need to be protected. A building may also prevent damage to equipment by children or trespassers.

The suction bay is often used as the foundation for the pump or the pump and motor. This arrangement frequently consists of a retangular pit enclosed on 3 sides by concrete walls. The pump may rest on a steel beam with a vertical suction pipe extending down in the suction bay the necessary distance below water. This arrangement is satisfactory for vertical type submerged pumps as well as for pumps set above water which require priming. Electric motors may be set on a pump on the beams spanning the bay. Diesel engines should rest on a substantial foundation which adjoins the suction bay. Another arrangement is to set the pump to the side of the suction bay with the suction pipe entering the pump horizontally and curving downward into the suction bay. One or two sets of screens should protect the suction bay from trash. The screens should have ample opening at low water to keep the velocity through the screen down to around 2 feet per second. Screens should be planned so they are easy to clean.

The pump or suction pipe should be submerged an adequate depth in order for the pump to operate efficiently. In the preliminary plans, a submergence of 3 feet below normal low-water pumping level

may be assumed for sea-level pumping. For 1,000 feet above sea level, the minimum submergence should be increased to 4 feet. These figures should be modified on specific advice from the pump manufacturer based on requirements of the pump selected.

The minimum clearance between the pump and side walls or suction pipe and side walls may be computed as 1.5 x pump size. For example, a 10-inch pump requires a minimum of 15-inch clearance from the side walls. The minimum clearance between the suction edge of the intake pipe and the floor of the suction bay may be designed equal to the pump size. For example, a 10-inch pump requires a 10-inch clearance between the bottom of the suction pipe and the floor of the suction bay. These dimensions should be modified on the advice of manufacturers.

Storage at suction bay.

Water storage at the suction bay is advantageous for several reasons. The suction bay should be controlled within small limits to provide a more constant operating condition. If the storage available at the suction bay is small, the pumping plant will draw the water down rapidly under ordinary conditions and pumps will take air and operate less efficiently. The pumping lift would be increased and frequent starting and stopping of the pumps will be required. A large storage at the suction bay will frequently make it possible to eliminate night operations and may result in decreased labor costs.

Where large areas are drained by pumping, it is frequently desirable to leave some sloughs and depressional areas undrained

for storage. Usually it is desirable to excavate the main ditch leading to the pumping plant deeper and wider than necessary to provide storage.

<u>Automatic Operation</u>.

Automatic operation of drainage pumping plants is feasible if electric power is used. This is particularly desirable in operation of small plants to save operating expenses and to provide constant control of drainage water. Automatic control may be obtained by a float which starts the motor when the water in the suction bay rises to a predetermined elevation. The pump then starts and gradually lowers the water and float. The water is pumped down to a level so the float trips a switch and cuts off the motor. Another device is to use an upper and lower electrode which will activate switches which start and stop the pump.

Pumping Plants in the Central and Southern Florida Flood Control District

The Central and Southern Florida flood control project is now under construction by the Corps of Engineers in cooperation with the flood control district organized under state laws. The project area includes Lake Okeechobee and some 15,000 square miles affected by the plan. The area of present and potential agricultural lands to be benefited amounts to 2,240,000 acres. The structural work includes levees, drainage canals, pumping plants, spillways, water-control structures and other works necessary to achieve flood control and drainage in the Florida Everglades.

Pump station No. 5A is typical of the 9 pumping plants. According to information furnished by the Corps of Engineers, station 5A will have 6 pumping units similar to the unit described below. Each unit consists of a horizontal axial-flow pump rated at 800 cfs at 11.1-foot static head. The power required to drive the pump is 1333 b.hp. The pump is driven by a diesel engine rated at 1470 b.hp. at 720 RPM. A silent chain transmission drives the pump at 125 RPM rated speed. Each pump has an elliptical intake measuring 12x18 ft. The pump house is of concrete block construction with structural steel framing designed to withstand hurricane winds. The foundations rest upon the limerock which is about 20 ft. below ground level. The pump house measures 108x210 ft.

In station 5A the pump impellers are 106 inches in diameter. In station 6 the 3 vertical pumps have impellers which are 135 inches in diameter. The latter pumps are rated at 975 cfs at 8.3-foot static head.

The pumping plants provide a positive regulation of flood and drainage waters which will permit a fuller utilization of the agricultural resources than would be possible without the pumping units. The following tabulation gives other pertinent data describing the plan.

PERTINENT STATISTICAL DATA
FOR ENTIRE PLAN

New levees (miles)	698
Existing levees, to be enlarged (miles)	82
New canals (miles)	112
Existing canals, to be enlarged (miles)	380
Pump stations (number)	9
Discharge capacity of pump stations (cubic feet a second)	540 to 4,610
Combined discharge capacity of pump stations (cubic feet a second)	26,020
Spillway control structures (number)	71
Culvert control works (number)	21
Diversion canals to Indian River (number)	7
Aggregate discharge capacity of 7 diversion canals (cubic feet a second)	23,570
Present regulatory limits of Lake Okeechobee (feet above mean sea level)	12.5 to 15.5
Storage capacity within limits (acre-feet)	1,300,000
Surface area of Lake Okeechobee (acres)	467,200
Size of Lake Okeechobee agricultural area (acres)	723,200
Combined size of conservation areas (acres)	860,200
Approximate cost of Comprehensive Plan	$300,000,000
Estimated cost of authorized works	$125,649,600
Percentage of completion of authorized works, Dec. 1953	16